CERTAIN PHASES IN THE GEOLOGICAL HISTORY OF THE NORTH AMERICAN CONTINENT, BIOLOGICALLY CONSIDERED.*

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It is quite certain that there has never been a time in the history of mankind when the thoughts of men were so eagerly turned to biological subjects as they are to-day; nor has there ever before been a time when an intelligent knowledge of them was so broadly diffused among cultivated persons. An earnest desire is everywhere manifested by such persons to obtain substantial knowledge concerning the animal and vegetable life of the earth, and of the broad significance of that life, which is revealed by a comparative study of its myriad forms. The investigator immediately finds that this subject, although it is so comprehensive and so complex, is only a fragment of a great history of life, which extends back through unnumbered ages. He finds himself at once confronted by questions concerning successive multitudes of former denizens of the earth, the physical conditions which prevailed when they existed, the probable lines of descent by which they came into being, and by which their successors have come down to the present time; and the manner in which those lines have probably originated and been preserved from destruction through successive geological periods.

This prevalent spirit of inquiry among men has been the cause of a vast amount of patient and exhaustive research, and it has also resulted in a large accumulation of knowledge. But it cannot be denied that every investigating naturalist, although he may fully accept the doctrine of evolution, finds the subject of the origin and derivation of the various groups of animals that now inhabit the earth, and those which have inhabited it during past geological time, to be beset with many difficulties and uncertainties.

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As a rule, too, he finds that the questions which arise in connection with the probable manner in which the various groups of animals have originated and become distributed over the earth are too complex to allow of their reduction to even approximately simple propositions. Still, the accumulated results of the various and extensive investigations which naturalists have made of late years have placed the general subject of the evolution of organic forms in such a condition as a working hypothesis, that some of its various divisions may be treated with considerable detail, even with reference to extinct faunas. Furthermore, in a great number of cases, the facts which have been observed are of such a character as to warrant opinions of so important a nature that they may be legitimately used as a basis for philosophical discussions. It is mainly upon such facts and opinions as these that the following remarks are based; and while the conclusions and opinions which are here expressed are believed to be fully warranted by known facts, it is only too evident that much, which it is very desirable to know in this connection, still remains beyond our reach.

That I may more clearly present my subject, I submit the following statement of certain views which I hold in relation to it; and, for the purpose of greater conciseness of statement in the remarks which are to follow, I shall refer to those views somewhat as if they were supported by established and acknowledged facts.

The general subject of the probable origin of the different forms of animal life, and their perpetuation through geological time being so broad, I must confine myself to such small portions of it as my studies have led me to understand as having an important bearing upon the geological history of the North American continent. I must, furthermore, confine myself to such portions of the subject as relate to terrestrial life only, leaving largely out of consideration the subject of marine life.

Since the points I wish to present are somewhat disconnected by our present imperfect knowledge, I must trust to making their relevancy more apparent when I come to make the proposed application

of them. A discussion of formerly existing vegetable forms would also be of great interest, but I must omit all except incidental reference to that subject also.

In all investigations into the history of ancient life upon the earth, regard must be had to the functions that animals perform, and to the conditions under which those functions are executed. The requisite conditions for the performance of the physiological functions in the simplest animal forms, the Protozoa, for example, render it practically certain that the primary origin of animal life occurred in water; and it doubtless occurred in the sea. The first animal life having necessarily been of aqueous origin, we must assume that the first air-breathing animals were developed from those of aqueous respiration.

Fresh-water mollusks and fishes, especially the former, have, I believe, primarily become such by a change from their originally marine habitat, mainly by compulsion; that is, their progenitors lived in the sea and became land-locked by the unequal elevation of the sea bottom upon, or over which, they lived while the continental areas were in process of elevation. The waters of the districts thus inclosed and elevated above the level of the surrounding sea became first brackish, and then fresh, in consequence of the influx of fresh water from the drainage of the surrounding land, and a consequent outflow into the open sea. Those of the sea-born animals which became thus inclosed, and which were capable of conforming to the new conditions, did so, and peopled the river systems which were produced in connection with, and which succeeded, these fresh-water lakes. Those which could not thus conform to the new conditions became extinct; and as these appear to have constituted the larger part of every fauna which became land-locked in the manner referred to, we may reasonably conclude that the lines of descent of many of the groups of marine animals have been broken by this means.

River systems have resulted upon the disappearance, by final drainage, of the fresh-water lakes just mentioned, the inlets having

been prolonged across the former lake bed as upper branches of the system, the former outlet becoming the main stream, and the whole a finished river system, with its fauna derived from the lake in which the system originated.

It is a well-known fact that many fishes, in connection with their breeding habits, pass from marine to fresh waters, and return to marine, with entire indifference to the change. Again, some existing so-called land-locked fresh-water fishes are believed by naturalists to have become such by choice, or by a failure on their part to continue their periodical returns to the sea where their kind originated, even when there was no apparent physical obstacle to their returning. It is probable that many similar cases have occurred in former geological periods, and also probable that a few mollusks and other invertebrates have, during those periods, in like manner changed from a marine to a fresh-water habitat; but I believe that, as a rule, fresh-water faunas have primarily become such by compulsion, in the manner that has just been suggested.

Admitting this proposition, we need not attempt to trace the genetic lines of fresh-water fishes as such any further back than the time of the compulsory land-locking of their progenitors; but this would not forbid speculation as to what kinds of marine fishes the fresh-water forms originated from.

It is possible that, in cases of sinking beneath the sea of land areas, upon which fresh waters with their faunas had become established in former geological periods, the sea has reclaimed and preserved alive some of its previously alienated mollusks and fishes; but this is a matter concerning which we can, at best, make only vague conjectures.

The reason why the animal life of fresh waters is so meagre, as regards the number and variety of kinds which they contain, when compared with the teeming and diversified life of the sea, are various. First, the presence of sodium-chloride and other salts in water has evidently been conducive of evolutional differentiation; and there can be no doubt that common salt has played a remark-

ably important part in the evolution of the different forms of animal life which have existed upon the earth. Second, in those cases of land-locking of marine animals by a rise of the sea bottom in the manner already suggested, only a part of the fauna then existing there would probably have become inclosed, because many of them would no doubt have escaped into the outer sea before they were fully surrounded by land. Third, only a part of those which were finally land-locked were able to survive the change from salt to fresh water. Fourth, a large proportion of marine gill-bearing animals appear to be, and always to have been, wholly incapable of living in fresh water.

Among those marine animals which seem to have been wholly or mainly incapable of surviving a change of habitat to fresh waters, and which, we may assume, did not escape land-locking, together with the other forms, in the numerous cases of the kind which have occurred in past geological periods, are several of the entire comprehensive groups into which the animal kingdom is divided. For example, we learn from the study of existing faunas that, with the exception of a few inconspicuous forms of the Cœlenterata, which are so abundantly represented in marine waters, this important sub-kingdom is not represented in any fresh waters; also, in fresh waters the entire classes, Echinodermata, Tunicata, Brachiopoda, Pteropoda, and Cephalopoda, are without any known representation. Besides these large deficiencies in fresh-water faunas, as compared with those of the sea, there are numerous minor, but no less important, deficiencies, occasioned by the entire absence of a considerable number of orders and families, as well as parts of others.

It would doubtless be unsafe to say that any of those animals could not possibly have survived a change to a fresh-water habitat; but there is much reason to suppose that they possess some inherent quality, which has prevented the survival of their ancient representatives, whenever their habitat may have been changed from a marine to a fresh-water condition. Indeed, if such changes of aqueous condition had been effected suddenly, it is probable that

none of the marine animals having aqueous respiration, which may have been thus inclosed by the rising land, would have survived in any instance. The comparatively few forms that did survive in fresh waters doubtless had much time in which to conform to their gradually effected new conditions.

It is probable that air-breathing mollusks have all been originally derived from those of aqueous respiration; and that this important change, and a consequent necessary change of habitat, has been accomplished mainly by a process of natural selection which was voluntary on their part, as compared with that by which the gill-bearing mollusks are assumed to have survived the change from salt to fresh waters. Again, that the air-breathing mollusks are confined to the class Gasteropoda, while other mollusks have evidently had equally good opportunities to become air breathers, is a significant fact, but one which, like that of the origin of the air breathers, I cannot discuss at this time.

While we may not doubt that the whole of the existing life of the globe has come down from former geological periods in unbroken genetic lines, the fact has not been demonstrated by tangible evidence; and it is well to consider briefly some of the causes of the imperfection of the geological record in that respect. By an investigation of this subject, we shall find that, while a multitude of such lines have certainly terminated at various periods before reaching the present time, it is not necessary to infer that any of them have been imperfect simply because we have not found the proof of their continuity in the shape of fossil remains. The lack of such proof is due to various causes. For example, only the hard parts of animals are capable of fossilization, and many animals have no hard parts. The greater part of the fossiliferous strata of the earth, which now exist as such, are not, and never can be, accessible to human investigation; and a vast amount of fossiliferous rocks, now classed as Azoic, may have once contained abundant remains of animal life, but which have become completely obliterated by metamorphism or other causes.

Finally, even the hard parts of animals, and especially those of land animals, are, and always have been, subject to rapid decomposition when exposed to atmospheric influence, although they may be preserved indefinitely when buried beyond the reach of such influence. It is this rapid destruction of the remains of land animals which is largely the cause that their geological history is so incomplete as compared with that of marine life.

An illustration showing how rapidly traces of important land faunas may have disappeared in former geological times is furnished by the living bison, or buffalo, of North America. Perhaps the earth has never witnessed such enormous numbers of any one species of large animals occupying such a broad continental area, as in the case of the buffalo. Its range once extended from the vicinity of the Atlantic to the mountains which border the Pacific coast, and from Mexico to near the Arctic circle, and its numbers were so great, even within the last twenty-five years, as to impede travel across the great plains of the West. So rapidly is this animal now passing away that it has disappeared from all but a fraction of its former range; and I venture the prediction that there are persons now living who will witness its entire extinction in its free state. It is true that relentless man has brought about this wholesale destruction, but that does not alter the force of the application I wish to make of the fact that the buffalo is passing away and leaving, by natural means, hardly any trace of its former existence. In all that region where it has lived so many centuries in abundance, traces of even its bones and teeth are rarely found.

Few places in all its former wide range have furnished the conditions necessary for the preservation, by sedimentary interment, of the bones of the buffalo beyond the reach of atmospheric influence; and the result has been that they have generally disappeared by decomposition as completely as the flesh has done. It is doubtless in a similar manner that the other great terrestrial faunas have been destroyed in former geological periods, for the remains of terrestrial animals have not usually fallen in conditions at all favora-

ble to their preservation, as compared with those of aqueous animals, which have had almost immediate sepulture.

I fear that in consequence of these remarks, following those with which I began to address you, some will be ready to suggest that naturalists have insecure ground to base their generalizations upon, as regards the origin of the existing animals of the earth by lineal descent from extinct faunas. I fully recognize the danger, in such an address as this, of giving undue prominence to the doubtful side of the subject. It is difficult also to satisfactorily present the affirmative side in a brief and concise manner, because that side is supported by evidence which is cumulative in its character, rather than reducible to precise propositions.

My object, however, in showing how completely great faunas may have been destroyed in past geological time is to plausibly account for the absence of their remains in places where our methods of reasoning lead us to expect them; and also to show that, because their remains have never been discovered, we should not necessarily infer that the animals which were necessary to complete a regular genetic scale never existed. Indeed, the fact that certain breaks in the zoological scale occur at certain horizons of the geological scale ought to lead us to infer that the missing animal forms did exist somewhere at such times, rather than that they never existed at all.

Now, as the study of the genetic descent of animals through geological time is based upon plan of structure, and the methods by which form is expressed, these indications may be ranged under two heads, namely, similarity of structure and identity of type. The former is a matter of tangible details, but the latter is in some sense ideal, or a manner in which form, in connection with structure, is expressed. The former is material in its character, but the latter is not the less real and important to the naturalist in the philosophical study of the comprehensive groups of animals.

The word "type," like many other words in the English language, is used with a variety of meanings; and as I use it here in a special sense, I may be excused for adding the following

words of definition: I regard a type as an ideal representation of a group of species which may embrace the whole of a comprehensive genus, or possibly more; or it may be only a subordinate division of a genus. I do not use the term as interchangeable with any of the terms which are used in systematic classification, such as species, genus, family, &c.; but sometimes it may be equal in scope to any of them, as, for example, when only a single species of a genus or of a family is known. It may, however, be properly substituted for species, genus, &c., in cases where, as in the Ostreidæ, for example, specific and generic diagnoses cannot be satisfactorily made. I shall, in the following remarks, have somewhat frequent occasion to refer to types, as just defined, and to their persistence through the geological periods, for I shall assume identity of type to be proof of lineal descent.

The fact that genetic lines of descent among animals have come down to the present time through successive geological periods being admitted, we may next inquire as to the manner in which they have been preserved, or rather how some of them may have escaped destruction during the physical changes which have occurred since those lines were established. I must necessarily make occasional reference to marine faunas in the following remarks, but it is my present purpose to discuss only those terrestrial and fresh-water faunas, the remains of which are found within the present limits or North America.

The manner in which lines of descent of the various families and types of animals have been preserved through the geological ages, and in which their perpetuation has been secured, has necessarily been different in the case of different kinds of animals. The sea having always occupied the greater part of the earth's surface, notwithstanding the shiftings of land and sea, which have, from time to time, taken place ever since land and sea first appeared upon the earth, one may readily understand how unbroken perpetuity of marine life may have been secured from the earliest dawn of life to the present time. It is not to be doubted that numberless lines of

descent of marine, as well as of land, animals have terminated during past geological periods, both from catastrophal and cosmical causes; but we may reasonably assume that all the multitudinous forms which people the sea to-day have been derived by direct lineal descent from those earliest forms which the sea contained at the dawn of life upon the earth. At least, if this has not been the case, there is nothing in the nature of the proposition that makes it improbable; that is, there have been no such changes upon the earth since life began as would at any time have necessarily destroyed all, or any considerable part, of the marine life previously existing.

The lines of descent of land animals have, however, been subject to greater vicissitudes; and the conditions under which they have originated and been perpetuated have been more various than those which have prevailed in the sea. Still, one may readily understand how land animals, which may have occupied a given region of the earth at any geological period when the physical conditions of the land which they occupied were changing, may, by their power of locomotion, have shifted to more congenial places, because, as a rule, such changes have not been too rapid to hasten unduly even the proverbially slow-moving snail. Thus land and palustral air-breathing mollusks, although they all require a moist habitat, could easily migrate to other congenial ground, as the land they were occupying may have become too dry for them or may have subsided beneath the sea. Therefore, their migration has always been practically unrestricted; and if, as is believed to have been the case, continental areas have been continuous, though subject to material changes and shiftings from early geological times, there appears to be no reason why, at least, many genetic lines of those animals should not have been continued from those ancient times to the present.

The case has been quite different as regards true fresh-water fishes and fresh-water gill-bearing mollusks, all of which can, of course, exist only in fluviatile and lacustrine waters. When we consider how

extensively the earth's surface features must have been changed during the successive geological periods, it would at first sight seem impossible that continuous lines of descent of such animals as these could have been preserved through any considerable portion of them. That is, those gill-bearing animals which may have occupied any given river system could not effect their distribution, or even their preservation, by migrating beyond its limits, in case their habitat should be destroyed by movements of the earth's crust. They could not pass over the land to any portions of other river systems, nor could they pass through the sea to reach the mouths of other rivers. We have, however, very satisfactory evidence that a large part of the living gill-bearing animals of North American fresh waters have come down by unbroken genetic lines from some period at least as remote as the close of the Cretaceous.

Now, a continuity of these lines of descent necessarily implies a continuity of their fresh-water habitat from the time of the origin of those lines to the present time. This continuity again implies the integrity of those river systems in which the mollusks originated, from those early times to the present. This last proposition, as a geological one, is comparatively new; but the labors of Powell, Gilbert, and Dutton have shown that rivers, in many instances at least, have been among the most permanent of geological, as well as geographical, features; that even the elevation of mountain ranges across their course has not swerved them from their ground; but that they have cut their way through the ranges as fast as they arose.

A vast number of rivers, which have drained the land in past geological times, have undoubtedly been destroyed by the submergence of the land and other causes; but I think we are justified in the assumption that many of the streams which were established, even as far back as the close of the Cretaceous period, are still flowing as parts of existing river systems. In this way, a large part of the gill-bearing faunas of the rivers of to-day have, by direct lineal descent, and in unbroken habitats, been transmitted from long past geological periods.

As to the manner in which the great vertebrate and articulate land faunas which now exist, and which have existed in former geological periods, have been respectively developed from lower forms, I have, at present, no suggestions to offer; but it is, nevertheless, assumed that they have been thus developed. It may be remarked, however, concerning their origin and perpetuation, that while certain minor faunas of terrestrial animals may have originated and been perpetuated upon comparatively small areas, it seems certain that the development and perpetuation of the great reptilian faunas, which existed during Mesozoic time, and also that of the wonderful mammalian faunas, whose remains are found in Tertiary strata, required large and congenial continental areas. It also seems necessary to infer that those continental areas, although they, from time to time, suffered material losses, and received considerable accessions of land, have been of true continental dimensions from early geological time.

The general subject of the geological history of continents is so complex and far reaching, and our present knowledge of that subject so fragmentary, that I shall not now attempt even an outline of such a history for North America; but I shall confine myself to what I conceive to be some of the more salient points of that history from a biological standpoint only.

If the geological history of animal life is incomplete and fragmentary, a like history of continental areas, especially as regards their location and outlines at different periods, is much more so. In the former case, we are guided in our investigations and conclusions by a known zoological system, which is based upon the abundant and diversified existing life of the earth. In the latter case, we are apparently without any available systematic guide; and the various phases of geological history of continents seem to have been the result of fortuitous movements of the earth's crust, in connection with sedimentation and sub-ærial and aqueous erosion. Not that those movements and processes have not been governed by physical laws, but the events, so far as we have yet learned in-

dications of them from the study of existing continents, appear to have lacked such relations with each other as to give any satisfactory history of continuous continental growth.

The opinion has prevailed among geologists that the North American continent, as a whole, had its origin as a result of the gradual contraction of the mass of the earth, by which certain depressions and elevations were formed upon its crust. The former, it has been understood, became permanently the ocean beds; and the latter, gradually rising above the level of the sea, became continents, whose outlines were changed, from time to time, by continued elevation, alternating with greater or less depressions; and also by coalescence of previously separated parts, and by accretions upon, and erosion from, their borders. This opinion implies that continental areas were pre-determined, that they have been permanent in their location, and that no such areas have ever occupied the broad spaces which are now occupied by the great oceans.

I do not now intend to discuss this theory, but I may say in passing, that a number of important facts do not, in my judgment, agree with it, and I regard it as more probable that continental areas have shifted from place to place in past geological time. But without reference to that theory, certain known geological facts seem to show that the present continent arose from the sea in separate portions, the larger and older being its northeastern portion; and that the western portions were elevated afterwards, and finally coalesced with the eastern. Furthermore, that the continent reached its present dimensions and shape by more or less extensive accessions upon its borders, especially those of the great gulf and the Pacific ocean.

While the following remarks will mainly refer to animal forms, certain known facts concerning the vegetable life of the past are so important in this connection that they should be at least briefly mentioned. If we regard the graphite which has been found in the Archæan rocks, and the petroleum of Silurian strata, as having had their origin in land plants, the history of the land vegetation of the

continent begins much further back than the earliest period in the strata of which we have yet discovered any indications of land animals. It is probable that land animals of the simpler kinds co-existed with the first established land vegetation; but with the exception of some imperfect remains of a species of land snail, and those of a few insects, which have been found in Devonian strata, the remains of the earliest known land animals have been found in strata of Carboniferous age. These Carboniferous land animals comprise a few batrachians, insects, and air-breathing mollusks; and although they are so few, they evidently represent portions of a large and varied fauna which then existed. They are also so highly organized and so diversified in character as to indicate that they originated in genetic lines which began in earlier periods, more or less remote.

The Carboniferous air-breathing mollusks referred to are both land and pond snails, and they have been found in widely separated portions of North America. They all belong to types which are represented by mollusks now living upon this continent, and by those also which are known to have existed here at intervening periods. These facts seem to indicate plainly that land surfaces of considerable extent have been continuous from that early period to the present; but they tell us nothing yet of continental movements which may have taken place in the meantime.

Our knowledge of the relations of the different portions of living non-marine molluscan faunas would naturally lead us to suppose that fresh-water gill-bearing mollusks existed simultaneously with those ancient air-breathers. Nevertheless, with the exception of certain bivalves, which have been found in Devonian strata, and others in the Carboniferous, which have been doubtfully referred to a fresh-water origin, fresh-water gill-bearing animals are not known to have existed before the beginning of Mesozoic time. It is, however, reasonable to suppose that such animals did exist in Paleozoic lakes and rivers, although no satisfactory traces of them, or of such bodies of fresh water, have ever been discovered.

As regards Paleozoic fresh-water fishes, they may or may not have existed. According to our present knowledge, teliost fishes, although they have been so abundant in both fresh and marine waters ever since Mesozoic time, had no existence in Paleozoic time. Marine ganoids were then abundant, and the Mesozoic, Tertiary, and living fresh-water ganoids may have been derived from some of them by lineal descent through fresh waters, but they probably originated by land-locking from the sea during later periods.

Viewing the animal and vegetable life of the earth as having been expressed in continuous series of forms, we ought not to expect to find that the geological ages were separated from each other by hard-and-fast lines, as regards the fossil remains of those series which characterize the strata of each age respectively. When such lines appear to be distinct, I think we are justified in assuming that the geological record is incomplete; or, in other words, that the forms necessary to complete that portion of the series really existed at the close of the one age and the beginning of the next; but that they are not represented by any discovered fossil remains.

The division between the Paleozoic and Mesozoic of North America, so far as the geology and paleontology of the continent is yet known, is much more distinctly marked than it is between the Mesozoic and Tertiary. This is especially true as regards plants. The greater part of the peculiar forms which characterized the abundant vegetation of the Carboniferous age seem to have suddenly ceased to exist with the ushering in of the Mesozoic age; and no representative of the dicotyledonous flora, which was so abundant in the Mesozoic and Tertiary, and which is so preponderant upon the earth now, has ever been discovered in any of the Paleozoic strata of the earth. From an evolutional standpoint, however, we cannot suppose that such an extensive and highly organized flora came suddenly into being; and we are left to infer that it was gradually developed somewhere, and during a period prior to that which is represented by the strata which contain the earliest known remains of the kind. The small number of land animals, that are

known to have existed in those early periods, do not seem to indicate so distinct a separation of the Paleozoic and Mesozoic as the plant remains do; for the types of the former have come down to the present day. The land snails, before referred to, furnish remarkable examples of types of animal life which have passed from the Paleozoic to the Mesozoic age, and thence down to the present time.

Although the biological evidence seems to be conclusive that, from the earlier Paleozoic to the present time, considerable portions of land have been continuously above the level of the sea within the area which is now occupied by the North American continent, we have no indication from such evidence as to the shape and dimensions which those early land areas successively assumed. We are, however, justified in the opinion that some of them were of great extent. From a biological point of view, also, I regard it as probable that extensive land areas formerly existed adjacent to that which the present continent occupies, and that they have been lost by submergence and erosion. This opinion, I think, derives strong support from the apparent sudden beginning, and the equally sudden termination, of certain extensive faunas of highly organized land animals, which are known to have existed and become extinct.

I do not forget, however, that our knowledge in this respect is slight, and that it is possible that the progenitors of these faunas may have existed within the bounds of the present continent, and that their remains may have been destroyed, so as to have escaped the scrutinizing search that has been made for them. But in view of all the known facts, both geological and biological, I at present hold to the opinion just expressed.

The existence of the immense and diversified dinosaurian faunas of Mesozoic time, subsisting, as they did, largely upon vegetation, seems necessarily to imply the co-existence of large land areas: also their apparent sudden introduction at the beginning of that age seems to make it necessary to conclude that their progenitors existed somewhere before the close of Paleozoic time, although no remains of those progenitors have been discovered. Because no

trace of the progenitors of either the dinosaurian faunas or dicotyledonous floras of the Mesozoic age have been discovered in previously existing strata, I am disposed to conclude that those progenitors originated upon, and occupied, land areas, which became gradually submerged, together with their ancient faunal and floral remains; while their living successors escaped by migration and dispersion to adjacent and unsubmerged portions of land, which are now within our continental area.

There is reason to believe that during the Triassic and Jurassic periods large continental areas were above the level of the sea, within and near the present limits of the North American continent; but we know comparatively little of the terrestrial life of those periods from actually discovered fossil remains.

If we except the Paleozoic bivalve mollusca of supposed fresh water origin, which have already been referred to, the remains of the earliest fresh-water molluscan fauna, of which we have any satisfactory knowledge, are found in Jurassic strata. These Jurassic mollusks belong to well-known types now living in the fresh waters of this continent; and they are also so highly organized as to point back to a still more ancient period, as that of their origin. These mollusks suggest the existence during the Jurassic period of fresh-water lakes and rivers within what is now Western North America, and the lakes and rivers in turn suggest the existence then of a considerable continental area. It is possible that those Jurassic rivers were, in part, portions of river systems which had held a persistent existence from former geological periods; but we have no direct paleontological evidence of it. This gill-bearing molluscan fauna seems also to be ancestrally related to faunas which are known to have existed in subsequent periods, as well as to certain fresh-water mollusks now living in North America.

A few species belonging to the fresh-water family Unionidæ have been discovered in Cretaceous strata of the western portion of this continent, but they all appear to be of different types from any of the family now living. I take this to be an indication that the

fresh waters in which those Uniones lived were not continued to later periods, as some other ancient streams of fresh water were, together with their molluscan faunas, and that the lines of descent of those mollusks were consequently cut off and their types extinguished.

While many rivers have persistently held their ground through several geological periods, despite even the elevation of mountain ranges across their course; the fact that great numbers of them have been destroyed in past geological time by the physical changes which have taken place in the regions they have occupied, is too evident to be questioned. One of the many examples of the destruction of bodies of fresh water which have become established upon the earth in former geological times is suggested by the presence of a true estuary deposit among the Cretaceous strata of Northern Utah. This deposit, which is a rare one of the kind, was evidently formed at the western border of the oceanic belt, which, it is understood, then traversed the whole North American area in a northward and southward direction, between two separate continental areas, and at the mouth of a river which then drained part of the western area. The region which that oceanic belt then occupied is now the heart of the continent, and all traces of the ancient river referred to are obliterated. Furthermore, the district which it drained to the eastward is now drained by other channels running in the opposite direction, into the Salt Lake Basin. I shall presently have occasion to refer again to this estuary deposit and to others which no doubt co-existed with it along the shores of the same sea.

The period which immediately succeeded that in which the last of the marine Cretaceous deposits were made, and which contains the estuary deposit that has just been referred to, namely, the Laramie period, witnessed the production of one of the most remarkable features which has ever characterized any continent. This feature was a great inland sea, holding both brackish and fresh waters, as the Caspian does now, but which was in other respects more like

the Black sea, because the latter has an outlet. It was immensely larger than either, but its full size is not known. Its deposits, however, are now found to occupy large districts, at intervals from Northern Mexico to the British Possessions, and from near the meridian of Great Salt Lake to western Kansas and Nebraska. It occupied the region which, in the immediately preceding period, was occupied by the oceanic belt before referred to. This belt was changed from an oceanic condition to that of an inland sea, by such a rise of the sea bottom at both the northern and southern portions of the belt as connected together the eastern and western continental areas, and gave the inclosed sea its inland position upon the great united continent.

That the waters of this great inland sea were soon considerably freshened, is shown by the fact that its deposits contain no remains of true marine forms. That its waters were in part brackish, is shown by the presence of the remains of a large variety of forms similar to those which now inhabit brackish waters only, and that they were in part fresh, is shown by the presence of fresh-water forms. A commingling of brackish and fresh-water forms is sometimes found in the strata of the Laramie group, but usually the two kinds are found respectively in alternating layers. This last named fact indicates that there were, from time to time, such oscillations of the bottom of this sea and its surrounding shores, as shifted the salt and fresh-water areas respectively, so that their deposits locally alternated with each other. And yet sedimentation in the Laramie sea went on continuously from the time when it was a part of the open ocean, and also continuously into parts of the fresh-water lakes which succeeded it.

That this great inland sea contained, at times, broad islands, and extensive marshes covered with a luxuriant vegetation, is shown by the abundant beds of lignite and other vegetable remains; and that its marshes were peopled by great dinosaurs and other reptiles, is shown by their remains, which are now found in various portions of the Laramie group. That many fresh-water streams emptied into

this great inland sea from the surrounding land, and that the sea had at least one great outlet, are necessary conclusions.

Now, the waters of the oceanic belt, which immediately preceded the Laramie sea, contained an abundant marine fauna, a large part of which necessarily died by the subsequent freshening of the waters, and in consequence of this, as we may suppose, many lines of genetic descent were broken. The surviving faunas were able to thrive in brackish and fresh waters respectively, both of which, as already stated, the Laramie sea contained. That the brackish-water forms, which survived in the Laramie sea, originated in the estuaries which existed upon its borders, before that sea was cut off from the open ocean, is probable, from the fact that those forms are largely identical in type with certain forms which are known to have existed in the same region just prior to the Laramie period. That the progenitors of the fresh-water Laramie species may have occupied some of the streams which emptied into the sea before it became land-locked is probable, but I regard it as also probable that they originated, at least in large part, in the Laramie sea.

Accepting the conclusions which have just been expressed, concerning the former existence and the character of the Laramie sea, which conclusions I have reached from a biological standpoint, we obtain a remarkably comprehensive view of the conditions which prevailed, during the Laramie period, upon what was destined to be our continent. There rises before the imagination of the investigator—an imagination chastened and curbed by a rational interpretation of facts—a great continent, whose outlines, it is true, are hidden in the mists of uncertainty; but he sees, resting upon its broad surface, an inland sea, the like of which for magnitude the earth has never known before or since. On every side stretches away a broad expanse of comparatively level country; a few mountains are seen in the distance, but not a peak of the great Rocky Mountain system has yet arisen. The land is covered with verdure and diversified by forests of wonderful growth; the busy hum of insects fills the air; the bright scales of fishes gleam in the waters of the sea;

huge terrapins crawl upon its beaches, and the jungles along its shores are peopled by a strange fauna, of which the dinosaurs are chief.

At the close of the Laramie period, there were such movements of the earth's crust as to change to dry land the greater part of the bottom of the Laramie sea, and the remainder was occupied by large bodies of water, greatly larger than our present great lakes, which then became wholly fresh, and so continued through a large part of the Tertiary period. It is in the deposits which those great fresh-water lakes have left that have been found the remains of the wonderful mammalian faunas, which have become so celebrated in North American geology. Other faunas, equally wonderful, have probably existed elsewhere, which have shared the fate that is now overtaking the buffalo, and that might have overtaken those Tertiary animals also, were it not for the very favorable conditions for entombment of their remains, which the sediments of those lakes afforded.

Up to the close of the Laramie period, through the whole of which a large dinosaurian fauna was continued, and in the strata of which there is a commingling of Cretaceous and Tertiary types, we have no evidence, in the shape of fossil remains, of the existence of any mammals except about a dozen small marsupials. The Eocene Tertiary strata, which rests directly upon those of the Laramie group, contain the remains of a mammalian fauna, which, for magnitude, diversity, and high organization combined, has never been excelled upon the earth. Nevertheless, we know nothing of the ancestry of this great fauna, so far as fossil remains are concerned, although the geological series of the preceding formations is quite complete; and those formations have been carefully searched for such remains. The dinosaurian fauna of the Laramie period seems to have ceased as suddenly as the mammalian fauna was introduced.

Since faunas have originated under favoring, and become extinct under adverse, conditions, the subject of the extinction of faunas is quite separate from that of their origination, although they are

in this case brought into immediate juxtaposition. The great dinosaurian fauna of the Laramie period doubtless originated much earlier, and came down under continuously favorable conditions from the earlier Mesozoic periods, and which favorable conditions were not interrupted by the land movements by which the Laramie sea was inclosed. Their final extinction appears to have resulted from an unequal struggle for existence, which ensued upon the introduction upon the land they had previously occupied of the immense mammalian horde whose remains are found in strata immediately overlying those which contain their own. The mammals thus became the leading forms of life upon this continent, as it then existed, as the dinosaurs had been during Mesozoic time.

For reasons already stated, we assume that the progenitors of this great mammalian fauna, whose appearance upon the earth seems to have been so sudden, really existed somewhere long previous to the time which is represented by the strata in which the remains referred to are found. I regard it as probable that those progenitors occupied some continental area, adjacent to that which the present one now occupies, and which, after the migration of the fauna to the region where their remains are now found, superimposed upon those of the dinosaurs, became destroyed or submerged.

It does not seem to me probable that this mammalian fauna could have previously occupied either the eastern or western portion of North America, as they are understood to have existed then, because those portions were already united at the beginning of the Laramie period, when the Laramie sea was formed, and their earliest known remains are found in strata which were deposited after the close of that period; that is, I hold that the known facts warrant the opinion that the immediate predecessors of the Tertiary mammalia referred to, themselves of Tertiary types, originated and long existed contemporaneously with the dinosaurian fauna of the Laramie period, but in a land which was separate from that which the latter occupied. Furthermore, that the land area which the mammalia then occupied is now unknown; but that it became united to the

dinosaurian region, as one of the results of those land movements by which the Laramie sea was destroyed.

I am well aware that this proposition is not fully established, but the series of strata preceding those which contain the mammalian remains is so complete as to indicate the prevalence of conditions, through at least the whole of the Laramie period, which were as favorable for mammalian existence as those of any subsequent period. And, although that series of strata has been quite as fully investigated as any other strata of the west, no trace of the ancestry of the mammalian fauna referred to has been discovered.

The immediate superposition of the remains of the mammals upon those of the dinosaurs, at the junction of the two formations which contain them respectively, indicates that the two mighty faunas met upon the same ground, in a contest for supremacy, which was decided in favor of the mammals, and that the dinosaurs then disappeared from the face of the earth. That this veritable "battle of the giants" was sharp and decisive, is probable, from the fact that there is no such association of the remains of the two faunas as to indicate that they lived together any considerable length of time.

Other strange and interesting land faunas succeeded those mammals which have just been referred to, but time will not permit me now to speak of them. I will therefore close my remarks with some reference to the manner in which, as I conceive, a large part of the gill-bearing fauna of the Mississippi river system has originated, effected its descent to the present time, and attained its present broad distribution.

The close similarity which exists between the molluscan fauna of the Laramie group and that of the present Mississippi river system, is apparent even upon casual observation. A large proportion of those mollusks are not only of the same types in each fauna respectively, but it is difficult to say how some of the fossils differ specifically from the living forms. This resemblance is strikingly exemplified among the Unionidæ. Those of that family now living in the Mississippi river system comprise a large variety of peculiar

forms, differing so much from those of other parts of the world that they are designated among naturalists as "North American types." The Uniones of the Laramie group, of which a considerable number of species have been discovered, are mainly of these North American types, and I, therefore, conclude that these fossil forms represent the living ones ancestrally. This conclusion of course implies that there has been an unbroken habitat for those fresh-water mollusks, from the Laramie period to the present time. Accepting this conclusion, we necessarily understand that the outlet of the Laramie sea continued to flow as a river after the disappearance of that inland sea and down to the present time, and that that river is now the Missouri, or one of its tributaries. The Laramie deposit also contains the remains of certain ganoid fishes, which are closely relatedto the gars (*Lepidosteus*) and dog-fishes (*Amia*) of the Mississippi, and the fishes doubtless effected their descent in the same waters with the Uniones.

If geologists have read the later history of the North American continent correctly, we learn that at the time those ancient inland bodies of water existed, the great Southern Gulf extended so far to the northward that it probably received the outlets of those bodies of water as separate streams. The same conditions would also have made the Ohio and Upper Mississippi separate rivers, emptying by separate mouths. While these two last-named rivers were separate from the western one, which drained the lakes and the inland sea, they doubtless had faunas which were quite different from that which now characterizes them. When, by a recedence of the borders of the gulf to the southward, all those rivers united their waters to form the main stream of the Mississippi, it is easy to see how the ancient fauna, which had come down the Missouri branch, may have become dispersed throughout the great river system.

I have thus endeavored to point out from among the great mass of evidence of the existence of life upon the earth during successive geological periods what portions of that evidence have reference to then existing land areas, for the bulk of it tells us of the ever

present sea. I have tried to indicate some of the relations which those areas probably had with our present continent, and to draw intelligible inferences, from the character of the fossil remains which represent some of the early forms of life, as to the conditions under which those forms then existed, and their relations to the now existing life of this continent. I have also offered suggestions concerning some of the changes of land and sea which, from time to time in the past, have probably taken place within and near the great area which is now occupied by the North American continent, and I have spoken also concerning what seem to be the results of those changes upon the life then existing, as well as upon that which now exists.

If my remarks shall have seemed in some respects desultory, I may, perhaps, claim that the nature of my subject has made them so. If, in the absence of tangible proof of the ancestry of some of the highly organized faunas and floras, whose remains are found in the strata of the different geological periods, I have assumed that such evidence has once existed, but that it has been destroyed or undiscovered; if, in attempting to explain these discrepancies, I have ignored the possibility of special creations—a belief which I am well aware is still popularly held—I have done it with no irreverent or antagonistic intent. As a naturalist, I must accept only natural explanations of natural phenomena. That I may have erred in judgment with regard to these questions, it would be folly for me to deny; but I claim to have been actuated in my study of them by a desire, which is the attribute of every true naturalist, to know the truth and the truth only. If you should not be disposed to accept the conclusions which I have reached, surely the facts I have stated cannot fail to interest you.

The subject which embraces these facts is an exceedingly broad one, and upon them may be based other discussions than those which I have attempted. Other lessons may also be drawn from them, one of which is that, in the accomplishment of her ends, Nature is extravagantly wasteful, and terribly cruel.

And yet, there is so much of order and harmony apparent in all her ways, so much of the genial sunshine of knowledge gained to the naturalist who studies them that, with the optimism which is inseparable from a sound mind in a healthy body, he has an enjoyment of his occupations such, I believe, as other men rarely know.